SSM/I Sea Ice Algorithm Inter-Comparison: Operational Case Studies from the National Ice Center

Paul McKenna[1]
Walter N. Meier[2]
Michael L. Van Woert[1], Michael Chase[1], and Kyle Dedrick[1]

[1]National Ice Center
Federal Office Building #4, Room 2301, 4251 Suitland Road
Washington, DC 20395

[2]U.S. Naval Academy
Oceanography Department
572M Holloway Road
Annapolis, MD 21402

Abstract-The National Ice Center (NIC) routinely provides weekly global sea ice analyses, daily analyzed and forecasted ice edge products, and tailored high-resolution satellite imagery in support of various U. S. Government agency requirements. Heavy reliance is placed on visible and infrared imagery from the civilian and defense meteorological satellites; however, in areas of persistent cloud cover the NIC takes advantage of passive microwave satellite data to fill these gaps. Currently the NIC analysts use the NIC Hybrid sea ice algorithm in the Northern Hemisphere and the Bootstrap sea ice algorithm in the Southern Hemisphere to complete their products. This particular choice of algorithms was initially based on the personal preference of individual analysts, and was then perpetuated through ongoing training programs. No rigorous assessment of the merit of each algorithm was undertaken. In July 2001 the NIC began an ongoing evaluation of the NASA Team, Bootstrap, NIC Hybrid, and NASA Team II sea ice algorithms. The evaluation was performed by comparing available, time-coincident, visible and infrared satellite imagery with the SSM/I products. To date, 13 cases have been collected and analyzed. The NASA Team II provides the consistently best estimate of the ice edge and the 90% concentration boundary. This paper discusses the study undertaken by the NIC and presents select case studies to illustrate the performance characteristics of the various algorithms.

I. INTRODUCTION

The U.S. National Ice Center (NIC) analysts primarily employ high-resolution visible and infrared imagery to produce weekly sea ice charts. Where these data and other sources are not available, SSM/I-derived sea ice concentration fields are used to complete the analysis. Currently, NIC uses the NIC Hybrid, a combination of the Cal/Val (CV) and NASA Team (NT) algorithms, in the Northern Hemisphere and the Bootstrap (BS) algorithm in the Southern Hemisphere. The choice of algorithm was initially based on the personal preferences of experienced ice analysts, and was then perpetuated through ongoing training programs. Here we present the first operation assessment of the strengths and weaknesses of the individual algorithms via comparisons with available visible or infrared Operational Linescan System (OLS) imagery [1].

II. SSM/I SEA ICE PRODUCTS

All of the algorithms evaluated in this study have been previously published and are extensively discussed in the literature. Additional information is also available at http://www.natice.noaa.gov/science. The CV algorithm (a modified version of the AES-York algorithm [2, 3]) has historically been the primary operational algorithm at the NIC. The Cal/Val relies upon the 37V and 37H channels near the ice edge and as a result is quite sensitive to thin ice. However, the algorithm is noted for often saturating quickly to 100% (and greater) ice concentrations. In contrast the NT [4, 5] and the BS [6,7] algorithms use ratios of the 19V, 19H, and 37V channels to determine ice concentration. The use of the 19 GHz channel in all regions reduces the ice edge precision. Moreover, they often dramatically underestimate thin ice concentrations, seeing thin ice as a mixture of thicker ice and open water. The BS algorithm employs seasonal tie-points for both the Arctic and Antarctic. This helps account for seasonal variability in the surface properties of the sea ice. The N2 algorithm [8] uses a methodology similar to the NT algorithm but also employs the 85 GHz channels to resolve some of the surface ambiguities, particularly those resulting from snow cover. In addition it uses an atmospheric radiative transfer model to correct for the atmospheric effects at the 85 GHz frequency. The algorithm is designed to retrieve improved ice concentration estimates near the ice edge while not saturating to 100% coverage at high ice concentrations.

The NIC Hybrid algorithm is a combination of the CV and NT algorithms [9]. Because this algorithm uses both the NT and CV algorithms it yields much greater sensitivity to thin ice and at the same time is designed to give more accurate retrievals in areas of high ice concentration. Unfortunately, because the algorithm switches between the standard and thin ice tie-points with a simple threshold, discontinuities can occur when switching from one regime to the other [10]. Because of its similarity to the NT and CV algorithms, the NH algorithm is not specifically evaluated in this study.

III. METHODOLOGY

In Spring 2001, NIC began generating daily SSM/I image products from the algorithms discussed above. Automated contouring routines were developed to produce geolocated contour lines of the compact ice boundary (>90% concentration) and the effective ice edge (<10% concentration). These contours were then overlayed on the OLS imagery for direct comparison.

IV. RESULTS

Of the 13 case studies collected, two from the Northern Hemisphere are presented here. Figure 1 shows an OLS visible image for the Barents Sea from August 27, 2001. Clouds are white, sea ice is gray, and open water is black in the image. The imagery shows that the N2 algorithm correctly identifies a large area of low ice concentration extending toward the northwest (circled). In contrast the CV largely misses this feature and the BS and NT algorithms show a much broader region of low ice concentration that is not borne out in the imagery. It is also noteworthy that the N2 algorithm correctly captures a >9/10 area just to the left of center in the image (A) and identifies the small opening to the east of the pack (B).

Figure 2 shows an OLS visible image from the Barents Sea for July 7, 2001. Again, clouds are white, sea ice is gray, and open water is black in the image. In this case the N2 does a reasonable job of identifying a polynya near the northern edge of the image (B). The CV algorithm misses this feature entirely while NT and BS significantly over-represent the size of the opening. In this case both the N2 and BS algorithms correctly identify the ice edge by turning towards the south. In contrast, the CV and NT cut across an area of 4-6/10 ice giving the impression that the ice edge is further north (A).

CONCLUSIONS

Due to the almost continual cloudiness over the Arctic and Antarctic regions, the importance of a reliable SSM/I algorithm for operational ice analysis cannot be overstated.

The NIC is tasked with providing weekly global sea ice analyses as well as tailored support for many different US government agencies. It is during this tailored support that ice edge and concentration boundaries become most critical and a reliable SSM/I algorithm is essential. Although this study was limited in both time and scale, the initial indications are overwhelming in favor of the NASA Team II algorithm. This may be attributed to the addition of the 85GHz channel. As a result of this study NIC now uses the NASA Team II algorithm exclusively in the Northern Hemisphere and in combination with the Bootstrap in the Southern Hemisphere.

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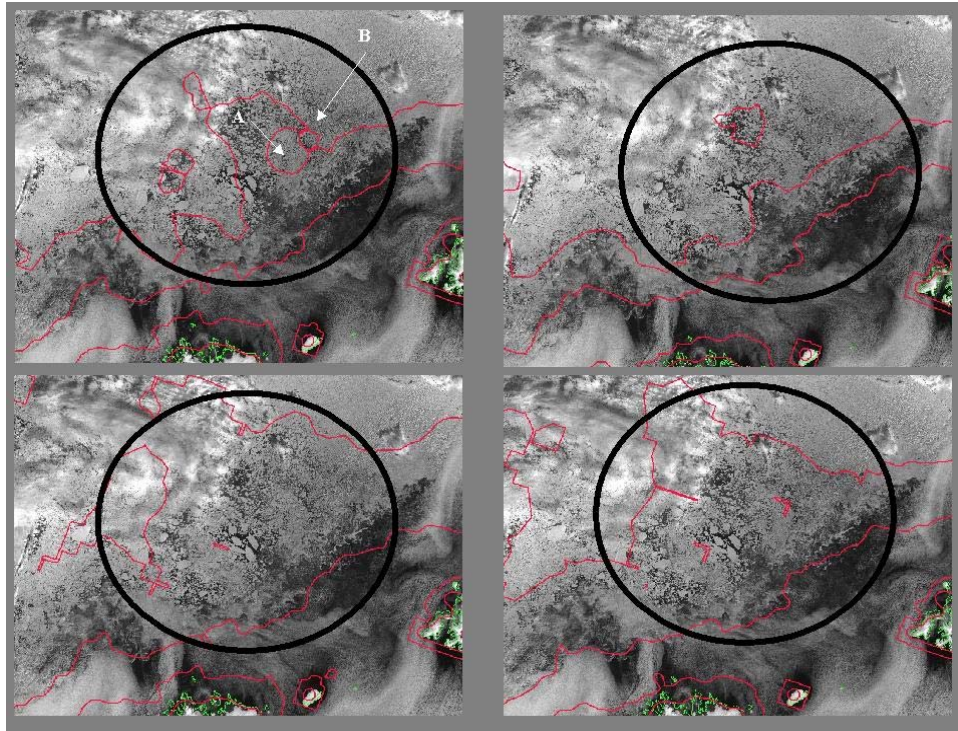
Fig 1- OLS visible image from Aug.27, 2001, over an area of pack ice northern Barents Sea. Contours of SSM/I consolidated ice (>90%, red line furthest from ice edge) and the ice edge (<10%, red line near ice edge) from NASA Team II (upper left), Cal/Val (upper right), NASA Team (lower left), and Bootstrap (lower right) are overlain on the OLS image. The circled area of interest is a weakness in the 9/10ths coverage.
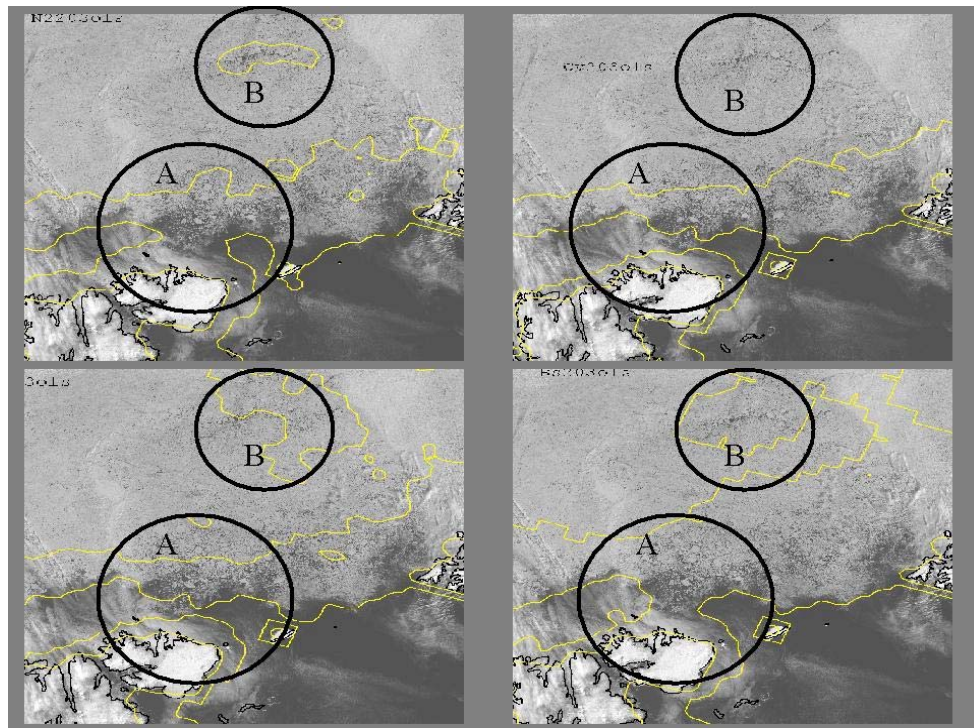

Fig.2- OLS IR image from Jul. 07, 2001, again it shows an area of pack ice northern Barents Sea. Contours of SSM/I consolidated ice (>90%, line furthest from ice edge) and the ice edge (<10%, line near ice edge) from NASA Team II (upper left), Cal/Val (upper right), NASA Team (lower left), and Bootstrap (lower right) are overlain on the OLS image. The circled area of interest is the pack ice with greater then 9/10ths coverage.

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